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ASTRONOMY.—*Condensation of the tables of the azimuth of celestial bodies.* G. W. LITTLEHALES, Hydrographic Office.

If finding the azimuth be viewed as a terrestrial measurement in connection with which the observed celestial body is considered to be projected vertically downward on the surface of the earth—that is to say, if the azimuth-angle be regarded as the angle whose apex is formed at the geographical position of the observer between his meridian and the great-circle arc passing through his geographical position and the geographical position of the observed celestial body, then it will become commonplace to regard any value of the azimuth as applying not only to the position of the particular celestial body observed but as applying besides to all geographical positions of which the great-circle passing through the geographical position of the observer and the geographical position of the observed celestial body is the locus; and, since every great-circle of the earth, except the equator itself, crosses the equator, there is always a point on the equator whose azimuth or true bearing from the observer is the same as the azimuth of the observed celestial body. The fact that this relation exists gives rise to the suggestion that the tables of the azimuths of celestial bodies at present in use, giving values for each latitude of the observer throughout a wide range of declination of the observed body, could be reduced in volume to the extent of omitting all except what relates to 0° of declination, provided only that convenient means be supplied for finding the difference of longitude or hour-angle between the meridian

TRUE BEARING OR AZIMUTH

LATITUDE

Hour Angle	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	Hour Angle h. m.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	
87 30	90 00	90 03	90 05	90 08	90 10	90 13	90 16	90 18	90 21	90 23	90 26	90 29	90 31	90 34	90 36	90 39	VI 00
85 00	90 00	90 05	90 10	90 16	90 21	90 26	90 31	90 37	90 42	90 47	90 52	90 57	91 03	91 08	91 13	91 18	50
82 30	90 00	90 08	90 16	90 24	90 32	90 39	90 47	90 55	91 03	91 11	91 19	91 26	91 34	91 42	91 49	91 57	40
80 00	90 00	90 11	90 21	90 32	90 42	90 53	91 03	91 14	91 24	91 35	91 45	91 56	92 06	92 16	92 27	92 37	30
77 30	90 00	90 14	90 27	90 40	90 53	91 06	91 20	91 33	91 46	91 59	92 12	92 25	92 39	92 52	93 04	93 17	20
																	10
75 00	90 00	90 16	90 32	90 48	91 04	91 20	91 36	91 52	92 08	92 24	92 40	92 56	93 11	93 27	93 43	93 58	V 00
72 30	90 00	90 19	90 38	90 57	91 16	91 34	91 53	92 12	92 31	92 49	93 08	93 27	93 45	94 03	94 22	94 40	50
70 00	90 00	90 22	90 44	91 05	91 27	91 49	92 11	92 32	92 54	93 16	93 37	93 58	94 20	94 41	95 02	95 23	40
67 30	90 00	90 25	90 49	91 15	91 39	92 04	92 29	92 54	93 18	93 42	94 07	94 31	94 55	95 20	95 43	96 07	30
65 00	90 00	90 28	90 56	91 24	91 52	92 20	92 47	93 15	93 43	94 10	94 38	95 05	95 32	95 59	96 26	96 53	20
62 30	90 00	90 31	91 03	91 34	92 05	92 35	93 07	93 38	94 09	94 39	95 10	95 40	96 11	96 41	97 11	97 40	10
60 00	90 00	90 35	91 09	91 44	92 18	92 53	93 27	94 02	94 36	95 10	95 44	96 17	96 51	97 24	97 57	98 30	IV 00
57 30	90 00	90 38	91 16	91 55	92 33	93 11	93 49	94 26	95 04	95 42	96 19	96 56	97 33	98 09	98 46	99 22	50
55 00	90 00	90 42	91 24	92 06	92 48	93 30	94 11	94 53	95 34	96 15	96 56	97 37	98 17	98 57	99 37	100 16	40
52 30	90 00	90 46	91 32	92 18	93 04	93 50	94 35	95 21	96 06	96 51	97 36	98 20	99 04	99 48	100 31	101 14	30
50 00	90 00	90 50	91 41	92 31	93 21	94 11	95 01	95 50	96 40	97 29	98 17	99 06	99 54	100 41	101 29	102 15	20
47 30	90 00	90 55	91 50	92 45	93 40	94 34	95 28	96 23	97 16	98 09	99 03	99 55	100 47	101 39	102 30	103 21	10
45 00	90 00	91 00	92 00	93 00	93 59	94 59	95 58	96 57	97 55	98 53	99 51	100 48	101 45	102 41	103 36	104 31	III 00
42 30	90 00	91 05	92 11	93 16	94 21	95 26	96 30	97 35	98 38	99 41	100 44	101 46	102 47	103 47	104 47	105 46	50
40 00	90 00	91 11	92 23	93 34	94 45	95 56	97 06	98 16	99 25	100 34	101 42	102 49	103 55	105 01	106 05	107 09	40
37 30	90 00	91 18	92 36	93 54	95 12	96 29	97 45	99 01	100 17	101 31	102 45	103 58	105 10	106 21	107 30	108 38	30
35 00	90 00	91 26	92 51	94 16	95 41	97 06	98 29	99 52	101 15	102 36	103 56	105 15	106 32	107 49	109 04	110 17	20
32 30	90 00	91 34	93 08	94 42	96 15	97 48	99 19	100 50	102 20	103 48	105 15	106 40	108 04	109 27	110 48	112 07	10
30 00	90 00	91 44	93 28	95 11	96 53	98 35	100 16	101 55	103 33	105 10	106 45	108 17	109 48	111 17	112 44	114 09	II 00
27 30	90 00	91 55	93 50	95 44	97 38	99 30	101 21	103 11	104 58	106 44	108 27	110 08	111 46	113 22	114 56	116 26	50
25 00	90 00	92 09	94 16	96 24	98 30	100 35	102 38	104 39	106 37	108 33	110 25	112 15	114 02	115 45	117 25	119 02	40
22 30	90 00	92 25	94 49	97 11	99 32	101 52	104 09	106 24	108 34	110 42	112 44	114 44	116 39	118 30	120 17	122 00	30
20 00	90 00	92 45	95 29	98 12	100 52	103 27	106 01	108 32	110 55	113 16	115 30	117 40	119 44	121 43	123 37	125 25	20
17 30	90 00	93 10	96 19	99 25	102 28	105 27	108 21	111 08	113 49	116 23	118 51	121 11	123 24	125 30	127 30	129 23	10
15 00	90 00	93 44	97 25	101 02	104 35	108 00	111 19	114 28	117 26	120 17	122 57	125 27	127 48	130 01	132 05	134 00	I 00
12 30	90 00	94 30	98 57	103 17	107 29	111 27	115 13	118 49	122 08	125 13	128 04	130 43	133 10	135 25	137 30	139 25	50
10 00	90 00	95 39	101 12	106 32	111 35	116 18	120 40	124 39	128 17	131 35	134 34	137 16	139 42	141 55	143 55	145 44	40
7 30	90 00	97 33	104 51	111 42	117 56	123 30	128 27	132 48	136 35	139 55	142 50	145 24	147 39	149 40	151 27	153 02	30
5 00	90 00	101 15	111 45	120 53	128 33	134 53	140 05	144 20	147 51	150 47	153 16	155 22	157 10	158 45	160 07	161 19	20
2 30	90 00	111 48	128 38	140 10	147 58	153 23	157 20	160 17	162 35	164 24	165 53	167 07	168 08	169 01	169 46	170 26	10

LATITUDE

Hour Angle		15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	Hour Angle h. m.	
°	′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		
90	00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	VI	00
87	30	90 39	90 41	90 44	90 47	90 49	90 51	90 54	90 56	90 59	91 01	91 03	91 06	91 08	91 10	91 13	91 15		50
85	00	91 18	91 23	91 28	91 33	91 38	91 43	91 48	91 53	91 57	92 02	92 07	92 12	92 16	92 21	92 26	92 30		40
82	30	91 57	92 05	92 12	92 20	92 27	92 35	92 42	92 49	92 57	93 04	93 11	93 18	93 25	93 32	93 39	93 46		30
80	00	92 37	92 47	92 57	93 07	93 17	93 27	93 47	93 47	93 56	94 06	94 16	94 25	94 35	94 44	94 53	95 02		20
77	30	93 17	93 30	93 42	93 55	94 08	94 20	94 32	94 45	94 57	95 09	95 21	95 33	95 45	95 57	96 08	96 19		10
75	00	93 58	94 13	94 29	94 44	94 59	95 14	95 29	95 44	95 59	96 13	96 28	96 42	96 56	97 10	97 24	97 38	V	00
72	30	94 40	94 58	95 16	95 34	95 51	96 09	96 27	96 44	97 01	97 18	97 35	97 52	98 08	98 25	98 42	98 58		50
70	00	95 23	95 44	96 05	96 25	96 46	97 06	97 26	97 46	98 06	98 25	98 45	99 04	99 23	99 42	100 00	100 19		40
67	30	96 07	96 31	96 54	97 18	97 41	98 04	98 27	98 49	99 11	99 34	99 56	100 18	100 39	101 00	101 21	101 42		30
65	00	96 53	97 19	97 46	98 12	98 38	99 04	99 29	99 55	100 20	100 44	101 09	101 33	101 57	102 21	102 45	103 07		20
62	30	97 40	98 10	98 39	99 09	99 37	100 06	100 34	101 02	101 30	101 57	102 25	102 51	103 18	103 44	104 10	104 35		10
60	00	98 30	99 02	99 35	100 07	100 39	101 10	101 41	102 12	102 43	103 13	103 43	104 12	104 41	105 10	105 38	106 06	IV	00
57	30	99 22	99 58	100 33	101 08	101 43	102 18	102 52	103 25	103 59	104 32	105 04	105 36	106 08	106 39	107 10	107 40		50
55	00	100 16	100 55	101 34	102 13	102 50	103 28	104 05	104 42	105 18	105 54	106 29	107 04	107 38	108 12	108 45	109 18		40
52	30	101 14	101 57	102 39	103 20	104 02	104 42	105 22	106 02	106 41	107 20	107 58	108 36	109 13	109 49	110 24	110 59		30
50	00	102 15	103 01	103 47	104 32	105 17	106 01	106 44	107 27	108 09	108 51	109 31	110 12	110 51	111 30	112 08	112 46		20
47	30	103 21	104 11	105 00	105 49	106 37	107 24	108 11	108 57	109 42	110 26	111 10	111 53	112 35	113 17	113 57	114 37		10
45	00	104 31	105 25	106 18	107 10	108 02	108 53	109 43	110 32	111 21	112 08	112 55	113 40	114 25	115 09	115 52	116 34	III	00
42	30	105 46	106 45	107 42	108 38	109 34	110 28	111 22	112 14	113 06	113 56	114 46	115 34	116 21	117 08	117 53	118 37		50
40	00	107 09	108 11	109 13	110 13	111 12	112 11	113 08	114 03	114 58	115 52	116 44	117 35	118 25	119 14	120 01	120 47		40
37	30	108 38	109 46	110 51	111 56	113 00	114 01	115 02	116 01	116 59	117 56	118 51	119 44	120 37	121 27	122 17	123 05		30
35	00	110 17	111 30	112 40	113 49	114 56	116 02	117 06	118 09	119 10	120 09	121 07	122 03	122 37	123 50	124 42	125 32		20
32	30	112 07	113 24	114 39	115 53	117 04	118 14	119 21	120 28	121 31	122 33	123 34	124 32	125 29	126 23	127 16	128 08		10
30	00	114 09	115 31	116 51	118 09	119 25	120 39	121 50	122 59	124 05	125 10	126 12	127 13	128 11	129 07	130 01	130 54	II	00
27	30	116 26	117 54	119 19	120 42	122 01	123 18	124 33	125 44	126 54	128 00	129 04	130 06	131 05	132 03	132 58	133 51		50
25	00	119 02	120 35	122 05	123 32	124 55	126 16	127 33	128 47	129 58	131 06	132 11	133 14	134 14	135 12	136 07	137 00		40
22	30	122 00	123 38	125 13	126 43	128 10	129 33	130 52	132 08	133 20	134 29	135 35	136 37	137 37	138 35	139 29	140 22		30
20	00	125 25	127 08	128 47	130 20	131 49	133 13	134 33	135 49	137 02	138 11	139 16	140 18	141 17	142 13	143 06	143 57		20
17	30	129 23	131 10	132 50	134 25	135 55	137 20	138 39	139 55	141 06	142 13	143 17	144 16	145 13	146 07	146 58	147 46		10
15	00	134 00	135 49	137 30	139 04	140 33	141 55	143 12	144 26	145 33	146 38	147 38	148 34	149 27	150 17	151 04	151 49	I	00
12	30	139 25	141 11	142 50	144 21	145 45	147 03	148 15	149 23	150 26	151 24	152 19	153 10	153 58	154 43	155 26	156 05		50
10	00	145 44	147 23	148 54	150 17	151 34	152 44	153 48	154 48	155 43	156 34	157 21	158 05	158 46	159 25	160 01	160 34		40
7	30	153 02	154 28	155 45	156 55	157 59	158 57	159 50	160 38	161 22	162 04	163 42	163 17	163 50	164 19	164 50	165 15		30
5	00	161 19	162 23	163 20	164 11	164 57	165 39	166 17	166 51	167 23	167 52	168 18	168 43	169 05	169 27	169 46	170 05		20
2	30	170 26	171 00	171 30	171 57	172 22	172 44	173 03	173 21	173 38	173 52	174 06	174 19	174 31	174 41	174 51	175 01		10

TRUE BEARING OR AZIMUTH

LATITUDE

Hour Angle	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	Hour Angle h. m.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	VI 00
87 30	91 15	91 17	91 20	91 22	91 24	91 26	91 28	91 30	91 32	91 34	91 36	91 38	91 40	91 42	91 44	91 46	50
85 00	92 30	92 35	92 39	92 44	92 48	92 52	92 57	93 01	93 05	93 09	93 13	93 17	93 21	93 25	93 29	93 32	40
82 30	93 46	93 53	93 59	94 06	94 13	94 19	94 25	94 32	94 38	94 44	94 50	94 56	95 02	95 08	95 14	95 19	30
80 00	95 02	95 11	95 20	95 29	95 38	95 47	95 55	96 03	96 12	96 20	96 28	96 36	96 44	96 51	96 59	97 06	20
77 30	96 19	96 31	96 42	96 53	97 04	97 15	97 25	97 36	97 46	97 57	98 07	98 17	98 26	98 36	98 45	98 55	10
75 00	97 38	97 51	98 05	98 18	98 31	98 44	98 57	99 10	99 22	99 34	99 46	99 58	100 10	100 21	100 33	100 44	V 00
72 30	98 58	99 14	99 29	99 45	100 00	100 16	100 30	100 45	100 59	101 13	101 27	101 41	101 55	102 08	102 21	102 34	50
70 00	100 19	100 37	100 55	101 13	101 30	101 48	102 05	102 21	102 38	102 54	103 10	103 26	103 41	103 56	104 11	104 26	40
67 30	101 42	102 02	102 23	102 43	103 02	103 22	103 41	104 00	104 18	104 37	104 55	105 12	105 30	105 46	106 03	106 20	30
65 00	103 07	103 30	103 53	104 15	104 37	104 58	105 20	105 41	106 01	106 21	106 41	107 01	107 20	107 39	107 57	108 15	20
62 30	104 35	105 01	105 25	105 50	106 14	106 37	107 01	107 24	107 46	108 08	108 30	108 51	109 12	109 33	109 53	110 13	10
60 00	106 06	106 34	107 01	107 27	107 53	108 19	108 45	109 10	109 34	109 58	110 22	110 45	111 07	111 29	111 51	112 12	IV 00
57 30	107 40	108 10	108 39	109 08	109 36	110 04	110 32	110 59	111 25	111 51	112 16	112 41	113 05	113 29	113 52	114 15	50
55 00	109 18	109 50	110 21	110 53	111 23	111 53	112 22	112 51	113 19	113 47	114 14	114 40	115 06	115 32	115 56	116 20	40
52 30	110 59	111 34	112 08	112 41	113 13	113 45	114 17	114 47	115 17	115 47	116 15	116 43	117 11	117 37	118 04	118 29	30
50 00	112 46	113 22	113 58	114 34	115 08	115 42	116 15	116 48	117 19	117 50	118 21	118 50	119 19	119 47	120 14	120 41	20
47 30	114 37	115 16	116 54	116 31	117 08	117 44	118 18	118 53	119 26	119 58	120 30	121 01	121 31	122 00	122 29	122 56	10
45 00	116 34	117 15	117 55	118 34	119 13	119 50	120 27	121 02	121 37	122 11	122 44	123 16	123 47	124 18	124 47	125 16	III 00
42 30	118 37	119 20	120 03	120 44	121 23	122 03	122 41	123 18	123 54	124 29	125 03	125 36	126 08	126 40	127 10	127 39	50
40 00	120 47	121 32	122 16	122 59	123 41	124 21	125 01	125 39	126 16	126 52	127 27	128 01	128 34	129 06	129 37	130 07	40
37 30	123 05	123 52	124 38	125 22	126 05	126 47	127 27	128 06	128 45	129 21	129 57	130 32	131 05	131 38	132 09	132 40	30
35 00	125 32	126 20	127 07	127 53	128 37	129 20	130 01	130 41	131 19	131 57	132 33	133 08	133 42	134 15	134 46	135 17	20
32 30	128 08	128 57	129 45	130 32	131 17	132 00	132 42	133 22	134 01	134 39	135 15	135 51	136 24	136 57	137 29	137 59	10
30 00	130 54	131 44	132 33	133 20	134 05	134 49	135 31	136 11	136 50	137 28	138 04	138 39	139 13	139 45	140 16	140 46	II 00
27 30	133 51	134 42	135 31	136 18	137 03	137 46	138 28	139 08	139 47	140 24	141 00	141 34	142 07	142 39	143 09	143 39	50
25 00	137 00	137 50	138 39	139 26	140 10	140 53	141 34	142 14	142 52	143 28	144 03	144 36	145 08	145 38	146 08	146 36	40
22 30	140 22	141 12	141 59	142 45	143 29	144 10	144 50	145 28	146 04	146 39	147 12	147 44	148 14	148 44	149 12	149 38	30
20 00	143 57	144 45	145 31	146 15	146 56	147 36	148 14	148 50	149 25	149 57	150 29	150 59	151 27	151 55	152 21	152 46	20
17 30	147 46	148 32	149 15	149 56	150 35	151 12	151 47	152 21	152 53	153 23	153 52	154 20	154 46	155 11	155 35	155 58	10
15 00	151 49	152 31	153 11	153 48	154 24	154 58	155 30	156 00	156 29	156 56	157 22	157 47	158 11	158 33	158 54	159 15	I 00
12 30	156 05	156 43	157 18	157 51	158 22	158 52	159 20	159 47	160 12	160 36	160 58	161 20	161 40	162 00	162 18	162 36	50
10 00	160 34	161 06	161 36	162 04	162 30	162 55	163 18	163 40	164 01	164 21	164 40	164 57	165 14	165 30	165 45	166 00	40
7 30	165 15	165 40	166 03	166 25	166 45	167 04	167 23	167 40	167 56	168 11	168 26	168 39	168 52	169 04	169 16	169 27	30
5 00	170 05	170 22	170 38	170 52	171 06	171 20	171 32	171 44	171 55	172 05	172 15	172 24	172 33	172 41	172 49	172 57	20
2 30	175 01	175 09	175 17	175 25	175 32	175 39	175 45	175 51	175 57	176 02	176 07	176 12	176 16	176 20	176 24	176 28	10

LATITUDE

Hour Angle	46°	47°	48°	49°	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°	60°	Hour Angle h. m.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	90 00	VI 00
87 30	91 48	91 50	91 52	91 54	91 56	91 58	92 00	92 02	92 04	92 06	92 08	92 10	92 12	92 14	92 16	50
85 00	93 36	93 39	93 43	93 46	93 50	93 53	93 57	94 00	94 04	94 07	94 11	94 14	94 18	94 21	94 25	40
82 30	95 25	95 30	95 35	95 40	95 45	95 50	95 55	96 00	96 05	96 10	96 15	96 20	96 25	96 30	96 35	30
80 00	97 13	97 20	97 27	97 34	97 41	97 48	97 55	98 02	98 09	98 16	98 23	98 30	98 37	98 44	98 51	20
77 30	99 04	99 13	99 22	99 31	99 40	99 49	99 58	100 07	100 16	100 25	100 34	100 43	100 52	101 01	101 10	10
75 00	100 55	101 06	101 17	101 28	101 39	101 50	102 01	102 12	102 23	102 34	102 45	102 56	103 07	103 18	103 29	V 00
72 30	102 47	102 59	103 12	103 25	103 38	103 51	104 04	104 17	104 30	104 43	104 56	105 09	105 22	105 35	105 48	50
70 00	104 39	104 53	105 08	105 23	105 38	105 53	106 08	106 23	106 38	106 53	107 08	107 23	107 38	107 53	108 08	40
67 30	106 33	106 49	107 06	107 23	107 40	107 57	108 14	108 31	108 48	109 05	109 22	109 39	109 56	110 13	110 30	30
65 00	108 29	108 48	109 07	109 26	109 45	110 04	110 23	110 42	111 01	111 20	111 39	111 58	112 17	112 36	112 55	20
62 30	110 33	110 54	111 15	111 36	111 57	112 18	112 39	113 00	113 21	113 42	114 03	114 24	114 45	115 06	115 27	10
60 00	112 43	113 06	113 29	113 52	114 15	114 38	115 01	115 24	115 47	116 10	116 33	116 56	117 19	117 42	118 05	IV 00
57 30	114 59	115 24	115 49	116 14	116 39	117 04	117 29	117 54	118 19	118 44	119 09	119 34	119 59	120 24	120 49	50
55 00	117 24	117 51	118 18	118 45	119 12	119 39	120 06	120 33	121 00	121 27	121 54	122 21	122 48	123 15	123 42	40
52 30	119 58	120 27	120 56	121 25	121 54	122 23	122 52	123 21	123 50	124 19	124 48	125 17	125 46	126 15	126 44	30
50 00	122 43	123 13	123 43	124 13	124 43	125 13	125 43	126 13	126 43	127 13	127 43	128 13	128 43	129 13	129 43	20
47 30	125 38	126 09	126 40	127 11	127 42	128 13	128 44	129 15	129 46	130 17	130 48	131 19	131 50	132 21	132 52	10
45 00	128 43	129 15	129 47	130 19	130 51	131 23	131 55	132 27	132 59	133 31	134 03	134 35	135 07	135 39	136 11	III 00
42 30	131 56	132 28	133 00	133 32	134 04	134 36	135 08	135 40	136 12	136 44	137 16	137 48	138 20	138 52	139 24	50
40 00	135 16	135 48	136 20	136 52	137 24	137 56	138 28	139 00	139 32	140 04	140 36	141 08	141 40	142 12	142 44	40
37 30	138 43	139 15	139 47	140 19	140 51	141 23	141 55	142 27	142 59	143 31	144 03	144 35	145 07	145 39	146 11	30
35 00	142 17	142 49	143 21	143 53	144 25	144 57	145 29	146 01	146 33	147 05	147 37	148 09	148 41	149 13	149 45	20
32 30	145 57	146 29	147 01	147 33	148 05	148 37	149 09	149 41	150 13	150 45	151 17	151 49	152 21	152 53	153 25	10
30 00	149 44	150 16	150 48	151 20	151 52	152 24	152 56	153 28	154 00	154 32	155 04	155 36	156 08	156 40	157 12	II 00
27 30	153 41	154 13	154 45	155 17	155 49	156 21	156 53	157 25	157 57	158 29	159 01	159 33	160 05	160 37	161 09	50
25 00	157 47	158 19	158 51	159 23	159 55	160 27	160 59	161 31	162 03	162 35	163 07	163 39	164 11	164 43	165 15	40
22 30	162 04	162 36	163 08	163 40	164 12	164 44	165 16	165 48	166 20	166 52	167 24	167 56	168 28	169 00	169 32	30
20 00	166 32	167 04	167 36	168 08	168 40	169 12	169 44	170 16	170 48	171 20	171 52	172 24	172 56	173 28	174 00	20
17 30	171 19	171 51	172 23	172 55	173 27	173 59	174 31	175 03	175 35	176 07	176 39	177 11	177 43	178 15	178 47	10
15 00	176 15	176 47	177 19	177 51	178 23	178 55	179 27	179 59	180 31	181 03	181 35	182 07	182 39	183 11	183 43	I 00
12 30	181 32	182 04	182 36	183 08	183 40	184 12	184 44	185 16	185 48	186 20	186 52	187 24	187 56	188 28	189 00	50
10 00	186 56	187 28	188 00	188 32	189 04	189 36	190 08	190 40	191 12	191 44	192 16	192 48	193 20	193 52	194 24	40
7 30	192 23	192 55	193 27	193 59	194 31	195 03	195 35	196 07	196 39	197 11	197 43	198 15	198 47	199 19	199 51	30
5 00	197 53	198 25	198 57	199 29	200 01	200 33	201 05	201 37	202 09	202 41	203 13	203 45	204 17	204 49	205 21	20
2 30	203 24	203 56	204 28	205 00	205 32	206 04	206 36	207 08	207 40	208 12	208 44	209 16	209 48	210 20	210 52	10

| | | |

of the observer and the meridian of the point of intersection with the equator of the great-circle arc passing through the geographical position of the observer and the geographical position of the observed celestial body. With this difference of hour-angle together with the latitude of the observer, the abridged azimuth tables, or the column of 0° of declination of the present solar azimuth tables, may be entered in the usual columns of time and latitude, and the required azimuth will thus be found.

The present great-circle sailing charts issued by the Hydrographic Office are constructed upon the gonomonic projection, and hence afford the means of accomplishing this purpose. The procedure is simple. It consists of plotting the latitude of the observer on any selected meridian and the observed celestial body in a latitude equal to the declination on a meridian whose difference of longitude from the meridian selected to represent the meridian of the observer is equal to the hour-angle of the observed celestial body, and, having drawn a straight line through the two positions thus plotted, noting the difference of longitude between the intersection with the equator of the straight line so drawn and the meridian selected to represent the meridian of the observer. If the geographical position of the observed body lies on the opposite side of the equator from the position of the observer and beyond the limits of the chart, plot the latter point as if it were on the same side of the equator and note on the equator the longitudes of both points; then join these four points diagonally by straight lines, and the longitude of the intersection of the diagonal lines will give the longitude of the required intersection with equator of the great-circle arc joining the geographical positions of the observer and the observed celestial body.

When either the latitude of the observer or the declination of the observed celestial body is higher than 60°, there will be instances arising in which even the most ample of these charts will not suffice to extend, to its intersection with the equator, the required great-circle arc passing through the geographical position of the observer and the geographical position of the observed celestial body. In such cases resort may be made to a gnomonic chart, known as Godfray's great-circle sailing chart,

in which the geographical pole has been chosen as the point of tangency of the plane of projection. In this, however, since the parallels of latitude are represented by a series of concentric circumferences whose radii are equal to $r \times$ cotangent latitude, where r is any convenient linear magnitude and represents the radius of the earth, the equator can not be represented because the cotangent of 0° of latitude is an infinity; and hence the intersection of the straight line representing the great-circle arc passing through the geographical position of the observer and the geographical position of the observed celestial body must be sought on some parallel of latitude near the equator, such as the parallel of 20° of latitude which is made the boundary circle in Godfray's chart. The required azimuth is then found in the column of azimuths tabulated for that declination in the solar azimuth tables which is equal to the latitude of parallel upon which the intersection is found, which, in the case of intersections determined on the boundary circle of Godfray's chart, would be the column of azimuths for 20° of declination.

The condensed tables as here presented may be arranged to stand complete at one opening of a book of fair size; and hence, in addition to being free of the usual interpolations for declination, are rid of the disadvantage of turning from page to page in interpolating for latitude.

MATHEMATICS.—*Equations containing only one unknown constant to represent the parabola, the rectangular hyperbola, and certain exponential curves.* H. E. MERWIN, Geophysical Laboratory.

By completing the following expression $\frac{x_2-x}{y_2-y} = \frac{x_2-x_1}{y_2-y_1} \ldots\ldots$ for three points in rectangular coördinates, equations can be formed for the parabola, the rectangular hyperbola, and certain exponential curves, each equation containing only one unknown constant. In each case after solving for the unknown constant, C, any point on the curve can be located by substituting its known coördinate, x_3 or y_3, for x or y of the equation. The curves, represented by the equation, do not pass through the origin.

Equations I and Ia represent the same rectangular hyperbola.[1] If a definite value of x is given, equation I should be used, otherwise Ia.

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}+C\,(x-x_1)\ldots\ldots\ldots\ldots\ldots\text{I}$$

$$\frac{y_2-y}{x_2-x}=\frac{y_2-y_1}{x_2-x_1}+C\,(y-y_1)\ldots\ldots\ldots\ldots\ldots\text{Ia}$$

II and III are parabolas[2] with principal axes parallel to the x- and y-axes respectively.

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}+C\,(y-y_1)\ldots\ldots\ldots\ldots\ldots\text{II}$$

$$\frac{y_2-y}{x_2-x}=\frac{y_2-y_1}{x_2-x_1}+C\,(x-x_1)\ldots\ldots\ldots\ldots\ldots\text{III}$$

Exponential forms[3] are as follows:

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}C^{x-x_1}\ldots\ldots\ldots\ldots\ldots\ldots\text{IV}$$

$$\frac{y_2-y}{x_2-x}=\frac{y_2-y_1}{x_2-x_1}C^{y-y_1}\ldots\ldots\ldots\ldots\ldots\ldots\text{V}$$

Equivalent to IV is

$$\frac{y_2-y}{x_2-x}=\frac{y_2-y_1}{x_2-x_1}C^{x-x_1}\ldots\ldots\ldots\ldots\ldots\ldots\text{IVa}$$

Equivalent to V is

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}C^{y-y_1}\ldots\ldots\ldots\ldots\ldots\ldots\text{Va}$$

[1] On expansion equation I becomes $A+Bx-Cxy+Dy=0$, where $A=y_2\left(\frac{x_2-x_1}{y_2-y_1}-Cx_1\right)-x_2$, $B=1+Cy_2$, $D=Cx_1-\frac{x_2-x_1}{y_2-y_1}$.

[2] By expansion II becomes $A+By-x+Cy^2=0$, where $A=x_2-y_2\left(\frac{x_2-x_1}{y_2-y_1}+Cy_1\right)$, $B=\frac{x_2-x_1}{y_2-y_1}-C\,(y_2-y_1)$.

[3] IV may be written $A+x+B\,(D-y)\,C^{x-x_1}=0$, where $A=-x_2$ $B=\frac{x_2-x_1}{y_2-y_1}$, $D=y_2$. Or it may be written in the form $y=\frac{a}{C^x}+\frac{x}{C^x}+d$.

Proper choice should be made between IV and IVa or between V and Va so that the logarithm of C will be positive. The exponential curves contain a flexure. On one side of the minimum (or maximum) they extend out indefinitely from both axes; on the other side they reflex and tend to become parallel to one axis. The end without the flexure is intermediate in curvature between a parabola and a rectangular hyperbola. Fig. 1 shows the character of thse curves. They can be made to pass through any three given points of which at least two must be on the non-reflex portion.

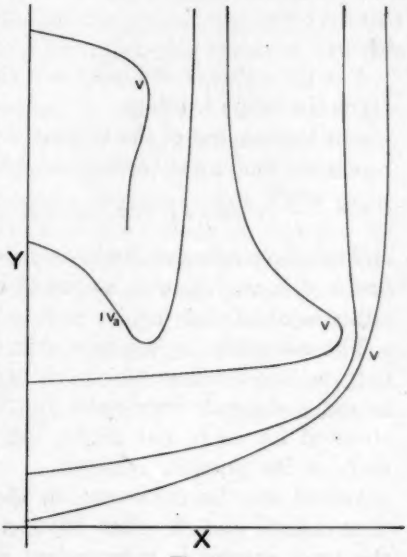


Fig. 1.

PHYSICS.—*The testing of potentiometers.* FRANK WENNER and ERNEST WEIBEL, Bureau of Standards.[1]

For precise measurements with a potentiometer the errors in the adjustment of the resistance sections or coils in the apparatus must be known. These errors can be determined by measurements of the resistances of the various sections but, without some systematic method of applying corrections, they are not easily allowed for in the use of the potentiometer.

We have found that it is convenient to express the relation between the known electromotive force, the unknown electromotive force, the readings and the corrections by the formula

$$E = f[(e_1 + a_1) + (e_2 + a_2) + \text{etc.}](1 + b + c + d) \quad (1)$$

[1] Presented at the Washington, 1914, meeting of the American Physical Society.

where

E is the value of the unknown electromotive force

f is the range readings

e_1 is the reading of the highest dial

e_2 is the reading of the next highest dial, etc.

$c = \frac{s-2}{s}$ where s is the value of the known electromotive force and s is the reading of the known electromotive force dial or dials, and b, d, a_1 and a_2, etc., are small corrections due to errors in the adjustment of the various resistance sections.

The correction a_1 depends only on the reading e_1, a_2 depends only on the reading e_2, etc., b depends only upon the reading s, and d depends only upon f. A table can therefore be constructed for each dial giving the corrections corresponding to each of its possible readings.

Let R_e be the resistance in the potentiometer between the E-terminals and R_s that between the S-terminals. Then if the total current is independent of the settings of the various switches or plugs,

$$E = S R_e/R_s = f[(e_1 + a_1) + (e_2 + a_2) + \text{etc.}] (1 + b + c + d) \quad (2)$$

Thus if R_e/R_s is determined for the various readings of f, of e and of s the corrections b, d, a_1, a_2, etc., can be determined.

In order to reduce the time required for making the measurements and to obtain the data in such form that the corrections can be more easily calculated, a special piece of apparatus was constructed and has been in use during the past two years. This apparatus which we shall call a *ratio-set* has been found to furnish a rapid and direct means for calibrating all types of potentiometers which have so far been submitted to the Bureau of Standards for test. It is equivalent to 211,110 resistance sections of 0.01 ohm each, connected in series and so arranged that a branch connection (either to battery or galvanometer) can be made between any two adjacent sections. Or it is equivalent to a slide wire on which contact can be made at 211,110 points. The apparatus is made of 100 resistance sections, 20 of each of the following denominations; 100 ohm, 10 ohm, 1 ohm, 0.1 ohm, and 0.01 ohm. Five dial switches serve to shift resistance sections

from one side to the other of the branch connection, or to cut out sections on one side and insert corresponding sections into the other side.

In use the ratio-set is connected in parallel with the potentiometer to be tested in such a way as to form two arms of a bridge, while the potentiometer forms the other two arms. This arrangement constitutes a Matthiessen and Hockin bridge. The ratio-set is adjusted so that a balance of the bridge is obtained for each setting of the dials of the potentiometer for which corrections are desired. The corresponding readings of the ratio-set (when connected for known errors in its resistance sections) give data from which the corrections b, e, a_1, a_2, etc., of equation (1) can be calculated. Certain adjustments are made such that the corrections are obtained almost directly from readings of the potentiometer and ratio-set.

PHYSICS.—*Adjustments of the Thomson bridge in the measurement of very low resistances.* F. WENNER and E. WEIBEL,[1] Bureau of Standards.

The purpose of this paper is to describe two new procedures for carrying out those adjustments which make the correction terms of the Thomson bridge equation negligibly small.

Both procedures require the use of a variable double ratio-set (so adjusted that, for any reading of the dial switches, the lack of equality of the two ratios, α/β, (fig. 1) is so small that no appreciable error is introduced on this account) and variable low resistance to be used in the connections, x_1 and x_2, between the terminals of the ratio-set and the potential terminals of the four-terminal conductors under comparison.

(1) With the test current supplied through the terminals b and b', the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

(2) With the test current supplied through the terminals n and o, the bridge is balanced by an adjustment of the variable low resistance forming a part of x_1.

[1] Paper to be published in the Bulletin of the Bureau of Standards.

(3) With the test current supplied through the terminals n' and o', the bridge is balanced by an adjustment of the variable low resistance forming a part of x_2.

(4) With the test current supplied through the terminals b and b', the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

In the other procedure the test current is supplied through the terminals b and b' only, but means are provided for connecting the terminals n and o, and n' and o' by conductors of low resistance. The adjustments are made in 4 steps, of which (1) and (4) are the same as given above. In (2) the terminals n and o are

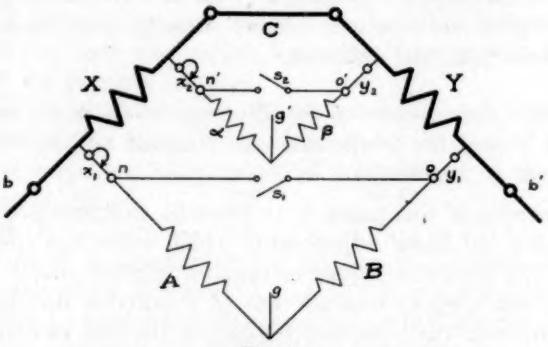


Fig. 1.

connected, while the bridge is balanced by an adjustment of x_1, and in (3) the terminals n' and o' are connected while the bridge is balanced by an adjustment of x_2.

Either procedure gives very accurately

$$x = ay/b \qquad (1)$$

where x and y are the resistances of the four-terminal conductors under comparison; and A and B are the resistances between n and g, and g and o, when the final adjustment is made.

Both procedures differ from those previously used mainly in that they do not require changing over to a simple bridge by opening the low resistance connection between the resistances under comparison. Where the resistances under comparison

and the resistance of the connection between them are very low, it is more or less impracticable to change over to a simple bridge during the adjustments. In such cases these procedures have been found more satisfactory.

MINERALOGY.—*Melilite and other minerals from Gunnison County, Colorado.* ESPER S. LARSEN and J. FRED HUNTER,[1] Geological Survey.

INTRODUCTION

The minerals described in this paper were collected by the authors during the summers of 1912–13 in the course of the geologic mapping of the Uncompahgre quadrangle, Colorado, under the direction of Whitman Cross. All but the anatase are from a small complex of peculiar igneous rocks near Iron Hill on the east bank of Cebolla Creek opposite the Cebolla Hot Springs, and a few miles southeast of Powderhorn post office, Gunnison County, Colorado.[2]

The rocks mapped in this area are, in the order of their age, a coarse-grained rock made up largely of melilite for which the name Uncompahgrite is proposed, a pyroxenite which locally carries segregated bodies of titaniferous iron ore, a rock related to ijolite, soda syenite, cancrinite syenite, and nepheline gabbro (or essexite).

The anatase was found in veinlets along joint planes in a dioritic dike which cuts the pre-Cambrian rocks in the gully about half a mile northeast of the Lot Mine, a few miles east of north of the mouth of Powderhorn Creek and Powderhorn post office, and only a few miles north of the Iron Hill area.

MELILITE

Occurrence and association. Several bodies of rock made up chiefly of melilite and for which the name Uncompahgrite is

[1] Published with the permission of the Director of the United States Geological Survey.

[2] All locations are given with reference to the United States Geological Survey topographic map of the Uncompahgre quadrangle.

proposed were found in the drainage of Beaver Creek, in all, covering an area a little less than a square mile. The largest of these is between the forks of Beaver Creek; others are south of the main Beaver Creek. The rock of these bodies is about two-thirds or more melilite with considerable pyroxene, magnetite, perofskite, and apatite, and in places biotite, calcite, and other minerals. It varies greatly in texture but is commonly coarse, and cleavage pieces of melilite a foot across are not uncommon. The finest grained rock is hypidiomorphic granular with crystals averaging 1 mm. across. In the coarser rock the luster of the giant melilite individuals is mottled by large included crystals of the other constituents. The melilite is anhedral so far as observed.

Physical properties. The mineral has a rather perfect basal cleavage, which is better developed in some specimens than in others. Its hardness is about 5. The specific gravity of the analyzed specimen is 2.98.

Optical properties. The pyroxene and ore are somewhat irregularly distributed in the large melilite crystals so that considerable sized fragments of melilite can be obtained nearly free from inclusions. The melilite is nearly colorless, to gray, and has a noticeably greasy luster. Splinters are clear and transparent but carry scattered, minute inclusions of opacite—probably magnetite. The gray color and lack of transparency of rather thick masses are due to these inclusions. In thin sections the melilite is colorless, and contains large crystals up to several centimeters across of pyroxene, apatite, calcite, magnetite, and perofskite in addition to the minute inclusions of opacite which are commonly collected in irregular areas or streaks. In the finer-grained rocks, sections of melilite with the maximum birefringence show a well-developed cleavage (001). Powdered fragments of the mineral commonly lie on the basal cleavage and hence are normal to the optic axis. The mineral is uniaxial and negative. The indices of refraction were measured on two polished plates from the analyzed specimen and also on polished plates from two other specimens from different outcrops. The following values were found: Coarse, analyzed material. $\omega_{Na} = 1.6319$ and

1.6326, av. 1.6323; ϵ_{Na} = 1.6254 and 1.6259, av. 1.6257; $\omega_{Na} - \epsilon_{Na}$ = 0.0066; $(\omega - \epsilon)$ measured = 0.007. In medium-grained material from another locality, ω_{Na} = 1.6327 and 1.6336, av. 1.6331; ϵ_{Na} = 1.6270 and 1.6273, av. 1.6271; $(\omega_{Na} - \epsilon_{Na})$ = 0.0060. In fine-grained material from a third locality, ω_{Na} = 1.6327; ϵ_{Na} = 1.6258; $\omega_{Na} - \epsilon_{Na}$ = 0.0069. Repeated measurements on a single plate checked to within 0.0002 so that the differences shown above are due to an actual difference in the values for different fragments.

In the greater part of the thin sections examined the melilite shows normal grayish interference colors almost identical with those of the associated apatite. In a few it shows abnormal blue colors and has a birefringence considerably lower than that of the associated apatite.

Resemblances. In the hand specimen the melilite closely resembles nephelite and, indeed, it is not always possible to distinguish between the melilite of some of the melilite rocks and the nepheline of some of the associated ijolites without the aid of a microscope. It is also difficult to distinguish the melilite rocks from some of the associated apatite-rich rocks, and chemical tests are necessary in some cases as the two minerals are similar both megascopically and microscopically. The apatite is whiter than the melilite and in thin sections it lacks cleavage and is commonly clearer than the melilite; otherwise its optical properties, when in granular aggregates, are almost identical with those of melilite.

Chemical properties. Material for the chemical analysis was carefully picked by hand from one of the coarse-grained specimens collected from an outcrop about 100 yards northeast of the point at which the mapped road up the south fork of Beaver Creek crosses that creek and about a mile above the mouth of North Beaver Creek. A careful microscopic examination of the sample showed the presence of a small amount of calcite and apatite, still less of pyroxene, and a very little opacite as small inclusions in the melilite. The mineral gelatinizes readily when treated with weak acids.

The following analysis (1) was made by W. T. Schaller in the laboratory of the United States Geological Survey. Analysis (2), which is of melilite from Capo di Bove, Italy, is given for comparison.

TABLE 1

ANALYSES AND RATIOS OF MELILITE

	1	1a	RATIOS		2
SiO_2	42.07	44.13	732	710	41.09
Al_2O_3	10.30	10.80	106	103	10.93
Fe_2O_3	0.50				3.40
TiO_2	0.20				
FeO	2.18	2.04	28		
MnO	0.16	0.16	2		
MgO	4.15	4.35	108	787	5.87
CaO[1]	35.41	34.63	618		34.78
Na_2O	3.24	3.40	55		3.40
K_2O	tr.	tr			0.68
P_2O_5	0.82				
CO_2	0.90				
H_2O	0.47	0.49			0.24
	100.40	100.00			100.39

1. Melilite from Beaver Creek, Gunnison County, Colorado. W. T. Schaller, analyst.

1a. Analysis computed free from apatite, calcite, magnetite, and perofskite.

2. Melilite from Capo di Bove, Italy. Bodlaender, analyst.

[1] BaO and SrO were not determined. The melilite rock contains 0.28% BaO and 0.35% SrO and this is believed to be in the melilite.

Alteration. Two types of alteration of the melilite have been recognized, and both are believed to be due to contact metamorphism. In the more common type the melilite is altered to a very fine aggregate of garnet, diopside, and vesuvianite, with some calcite, zeolites, and several undetermined minerals. It appears to be a recrystallization of the melilite, probably without important additions or subtractions of chemical constituents. In the less common type the melilite is altered to a fibrous aggregate of a new mineral—cebollite, described in the following paper. The alteration begins along the cleavages and seams in the melilite, spreads out, and finally replaces all of that mineral. Melilite

has been found in all stages of this alteration, which is no doubt due to the action of water solutions, probably hot solutions from the intruding pyroxenite magma.

PEROFSKITE

The relatively rare mineral, perofskite, is an abundant constituent of the melilite rock, the pyroxenite, and the ijolite. It is one of the chief constituents of the magmatic segregations of "iron ore" which are abundant in the pyroxenite. These segregations are made up of about equal amounts of magnetite and perofskite with varying amounts of apatite and biotite. So far as observed there is no ilmenite present. Singlewald[3] and Brunton[4] have not distinguished this type of iron ore from the more common ilmenite-magnetite ore.

In the melilite rock the perofskite, which is commonly in grains or octahedral crystals, forms several per cent of the rock, and locally is next to melilite in abundance. The larger crystals are several millimeters across.

The perofskite is iron black in color and has a sub-metallic luster approaching adamantine. In appearance it differs from magnetite, chiefly in luster, and the two minerals are difficult to distinguish megascopically except by the lack of magnetism in the perofskite. It is even more difficult to distinguish from some of the titaniferous garnet.

In thin sections the perofskite is weakly birefracting and shows a complex of polysynthetic twin lamellae resembling the grating of microcline or less often the albite and pericline twins of plagioclase. It is translucent and, in transmitted light, is Saccardos umber[5] in color and is perceptibly pleochroic with the absorption

[3] Singlewald, J. T., The iron ore deposits of the Cebolla District, Gunnison County, Colorado: Econ. Geol., **7**: 560. 1912.

[4] Brunton, S., Some notes on titaniferous magnetite. Econ. Geol., **8**: 677. 1913. Iron stained plagioclase is mentioned as a constituent of the iron ore from the Cebollite District. We have found no plagioclase in the ore but some of the perofskite shows polysynthetic twinning somewhat resembling that of plagioclase and might have been mistaken for an iron stained plagioclase.

[5] Color 17″ k of Ridgway's "Color standards and nomenclature," 1912, Washington, D. C.

$Z > X$. Its index of refraction is 2.34 and its birefringence, about 0.002. In thin sections it is distinguished from the garnet, which is also common in the rocks, by its slightly different color and especially by its weak birefringence and twinning, which is uniformly present except in a few of the very small crystals.

TITANIFEROUS ANDRADITE

Black andradite garnet is present in most of the igneous rocks of the Iron Hill area but is especially abundant in the rock related to ijolite and locally is an important constituent of the soda syenite. Specimens of a soda syenite collected from near the contact with the pyroxenite on the southeast slope of the knob 9500′+ north of North Beaver Creek are made up of microperthite and somewhat less garnet which is interstitial to the feldspar. The garnets are commonly about a millimeter across, are anhedral, black, and of submetallic luster. In thin sections they are dark reddish brown and are not very different from some of the perofskite for which they were at first mistaken. Their index of refraction was measured by the imbedding method and found to be 1.907 ± 0.005.

An approximate analysis of the garnets was made by W. T. Schaller of the Geological Survey with the following results:

TABLE 2

APPROXIMATE ANALYSIS OF TITANIFEROUS ANDRADITE

SiO_2	34.30	
Al_2O_3	4.46	
TiO_2	5.08	(equals 4.57 Ti_2O_3)
Fe_2O_3	24.09	(total iron as Fe_2O_3)
CaO	31.06	
MgO	0.52	
	99.51	

The analysis shows that the garnet is an andradite rather high in titanium. A similar garnet is an important constituent of the ijolite and locally it is the chief dark mineral. Some parts of the ijolite are made up of coarse anhedral garnet and nephe-

line in about equal amounts with a little pyroxene, apatite, perofskite, biotite, magnetite, etc. Grains of garnet several centimeters across are not uncommon.

BLUE ANATASE

Beautiful, dark blue crystals of anatase were found in narrow veinlets and in the adjoining altered country rock about half a mile north of the Lot Mine. The veinlets are only a few millimeters across although the rock on either side is altered for several millimeters. These veinlets were found only in a single dike of a dioritic rock a few hundred feet across, but in this dike were observed in abundance for a distance of nearly a mile and doubtless continued beyond the limits of observation. They are commonly nearly parallel to the walls of the dike, but some trend across the dike, thus forming a network; they probably filled shrinkage joints in the diorite.

The anatase originally formed somewhat less than half the vein filling; the other minerals of the filling are altered to limonite and no trace of their original character was found. In addition to occurring in the vein anatase is present in disseminated crystals in the adjoining altered country rock.[6]

The anatase crystals are commonly well formed and are bounded by a large number of faces. Their habit is pyramidal, tabular, or prismatic. In size they reach a centimeter in greatest dimension. In color the mineral varies from deep blue to almost black. The lighter colored crystals are translucent and some, if of sufficient size, might make beautiful gem stones with their deep blue color and highly adamantine luster. An approximate chemical analysis showed that the blue mineral is essentially TiO_2. Optically it is uniaxial, negative, has a strong birefringence and an index of refraction (ω) of about 2.56.

[6] Specimens shown us by Mr. Frank L. Hess, of the Geological Survey, from near Hot Springs, Arkansas, show anatase and pyrite in veinlets and the accompanying altered country rock and somewhat resemble the material described in this paper.

MINERALOGY.—*Cebollite, a new mineral.* ESPER S. LARSEN and W. T. SCHALLER,[1] Geological Survey.

At several places, notably six-tenths of a mile southwest of the forks of Beaver Creek near Powderhorn, Gunnison County, Colorado, some of the melilite of the occurrence described in the preceding paper is altered to a dull, compact, white to greenish, fibrous aggregate, which on microscopical and chemical study proved to be a new mineral, for which the name *Cebollite*[2] is here proposed. In some specimens the melilite is replaced by a fibrous aggregate of cebollite with little else while in others bodies of the vesuvianite-garnet diopside type of alteration are scattered through the cebollite. In general the two types of alteration appear to be distinct. Thin sections show that the cebollite is in microscopic fibers, commonly arranged normal to the original cleavage of the melilite, or in fan-like or arborescent aggregates.

Physical properties. Cebollite has a hardness of about 5 and a specific gravity of about 2.96. It fuses at about 5 to a clear glass. On account of the small size of the fibers cleavage could not be recognized.

Optical properties. The mineral is white to greenish gray, The fibers are very minute and the optical properties could be determined only approximately. The indices of refraction as measured by the immersion method are: $\alpha = 1.595 \pm 0.003$; $\beta = 1.60$; $\gamma = 1.628 \pm 0.005$. The extinction is parallel and the elongation is positive. The fibers are too minute to yield a satisfactory interference figure but the mineral is biaxial and positive. The axial angle could not be accurately measured but 2E is about 80 ± 10° and hence 2V is about 58°. The mineral is probably orthorhombic. Cebollite may be identical with the mineral described by Rosenbusch[3] as an alteration product of melilite and considered by him to be a zeolite.

[1] Published with permission of the Director of the United States Geological Survey.

[2] Pronounced Cĕ- vŏi- 'lte. From Cebolla Creek in whose drainage the mineral was collected. As in the preceding paper, locations are with reference to the topographic map of the Uncompahgre quadrangle, Colorado.

[3] Mikroskopische Physiographie der Mineralien und Gesteine, I : 2, 4te Aufl., p. 72.

Chemical properties. The material selected for analysis represented the completely altered melilite and consisted mainly of cebollite but contained considerable garnet, diopside, and vesuvianite so intimately admixed that separation was found impossible. The analysis made by W. T. Schaller in the laboratory of the U. S. Geological Survey is given below in Column 1. In Column 2 the analysis is computed free from the insoluble portion which represents diopside, garnet, etc. In Column 3 the analysis of the fresh melilite is given for comparison.

ANALYSIS OF CEBOLLITE

By W. T. Schaller

	1	2	RATIOS			3
SiO_2	27.06	33.02	0.550	3.26	3×1.09	44.13
Al_2O_3	11.49	14.02	0.137	0.94	1×0.94	10.80
Fe_2O_3	2.81	3.43	0.021			
FeO	0.17	0.21	0.003			2.04
MnO						0.16
MgO	3.84	4.69	0.117	4.74	5×0.95	4.35
Na_2O	2.10	2.57	0.041			3.40
K_2O	tr.	tr.				tr.
CaO	29.27	35.72	0.638			34.63
H_2O-	none	none				
H_2O+	5.13	6.26	0.348	2.06	2×1.03	0.49
Insol.	18.05					
	99.92	99.92				100.00

1. Cebollite from 0.6 of a mile south of the forks of Beaver Creek, Gunnison County, Colo.

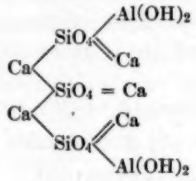
2. Analysis computed free from insoluble portion, diopside, garnet, vesuvianite, etc.

3. Melilite from Beaver Creek, Gunnison County, Colo.

The formula derived from the analysis is $3SiO_2 . Al_2O_3 . 5RO . 2H_2O$, in which R is chiefly Ca with smaller amounts of Mg, Na_2, and Fe. The ratio of $Na_2O : MgO + FeO : Ca$ is about 1 : 3 : 16. Considering all the RO as CaO, the formula of cebollite, $H_4 Al_2Ca_5Si_3O_{16}$ may be written in two ways, as follows:

1. $(SiO_4)_3 . Ca_5 . [Al(OH)_2]_2$.
2. $(SiO_4)_3 . (CaOH)_4 . Ca . Al_2$.

The powdered mineral, treated with water, does not react alkaline with phenolpthalein and adopting the suggestion of Clarke that for silicates the presence of the (CaOH) group is indicated by such a reaction, the second of the above two formulas becomes untenable and the formula of cebollite, $(SiO_4)_3.Ca_5[Al(OH)_2]_2$, is written structurally.



The mineral gelatinizes with acids and gives off water when heated in a closed tube.

Cebollite does not appear to be closely related to any other known minerals. It may belong to the zeolites although it contains a larger amount of MgO than is common in minerals of that group.

MINERALOGY.—*Wurtzite at Goldfield, Nevada.* F. L. RANSOME, Geological Survey.

In a report[1] on the geology and ore deposits of Goldfield, Nevada, sphalerite was recorded as being present in small quantity associated with some of the gold ore. Since that work was published, the studies of Allen and his associates[2] and of B. S. Butler[3] have given new significance to the occurrence of the hexagonal sulphide of zinc, wurtzite, which has generally been regarded as a rather rare mineral partly, no doubt, because it has been frequently overlooked.

Allen and Crenshaw have shown that the presence of wurtzite

[1] Ransome, F. L., The geology and ore deposits of Goldfield, Nevada. U. S. Geol. Survey Prof. Paper 66, 1909.

[2] Allen, E. T., Crenshaw, J. L., and Merwin, H. E., The sulphides of zinc, cadmium, and mercury; their crystalline forms and genetic conditions. Am. Jour. Sci. (4) **34**: 341–396. 1912.

[3] Geology and ore deposits of the San Francisco and adjacent districts, Utah. U. S. Geol. Survey Prof. Paper 80, pp. 93–95, 149–150, and 153–158. 1913.

is to be expected where ore containing zinc sulphide has been deposited by acid solution at temperatures below 300°C. The Goldfield ores, containing alunite and marcasite, two minerals formed in an acid environment, are believed to have been deposited comparatively near the surface by the mingling of descending waters containing sulphuric acid with ascending thermal waters containing hydrogen sulphide and probably alkali sulphides. Under such conditions, at least a part of the zinc sulphide present, as was orally suggested to me by my colleague Dr. J. B. Umpleby, might crystallize as wurtzite.

To test this suggestion some of the material collected in 1908 from the workings of the Mushett lease on the Miss Jessie claim, one of the few places in the district where zinc sulphide had been found at that time, was reëxamined. This ore was originally described as follows:

> The ore of the Mushett lease on the Miss Jessie claim northeast of the Red Top mine is structurally and mineralogically one of the most interesting in the district. The proportion of sulphides to gangue is greater than in most of the mines. The metallic minerals noted are pyrite, famatinite, bismuthinite, sphalerite, and a dark-gray mineral identical in appearance with that analyzed and described on page 116, and probably like it the new species goldfieldite. This material is rich in gold, specimens which to the naked eye show not a particle of the native metal yielding over $8000 a ton on assay. The crustification in the Mushett ore is not very regular, but the minerals have formed in the following general succession: (1) pyrite; (2) famatinite, bismuthinite, goldfieldite; (3) sphalerite; and (4) pyrite. The sphalerite in some places forms botryoidal crusts over the prisms of bismuthinite, which attain a larger size in this ore body than in other known occurrences in the district.
>
> The material forming the extreme outer crust of the nodular ores of Goldfield or filling interstices between the altered and incrusted rock fragments is in most places a soft mixture of alunite and pyrite.[4]

The so-called sphalerite is dark reddish brown, forms crusts rarely over half an inch thick and in places it shows a rather indistinct radial fibrous structure. Reëxamination shows that a little marcasite is present as minute botryoidal aggregates on some of the pyrite but is less abundant than in certain other rich Goldfield ores.

[4] Ransome, F. L., Op. cit., p. 165.

In thin section under the microscope a considerable part of the material, particularly that forming the inner portion of the crust, may be seen to consist chiefly of radial aggregates of distinctly birefringent prisms with very indefinite individual outlines. These fibers, which are clearly wurtzite, show a tendency to diverge from points on the inner surface of the crust, becoming less distinct toward their free ends where the birefringent aggregate grades into material that is chiefly sphalerite, containing here and there little flecks of wurtzite. In some aggregates the prisms have grown radially outward from small dark nuclei which appear to consist chiefly of ferruginous zinc sulphide, in part at least, wurtzite. As a rule the aggregates of wurtzite in addition to their radially fibrous structure show a noticeable although discontinuous concentric parting. In ordinary light the wurtzite and sphalerite are practically indistinguishable except in a few parts of the section where sphalerite may be recognized by its dodecahedral cleavage; but generally both sphalerite and wurtzite are traversed by a multitude of irregular cracks which mask any cleavage that might otherwise be visible.

Wurtzite in very intimate association with sphalerite and visually distinguishable from that mineral only by its birefringence, has been described from the Horn Silver mine, Utah, by B. S. Butler.[5] Mr. Butler's conclusion, which is apparently well supported, is that the wurtzite is younger than the sphalerite and was formed by the action of descending acid solutions, although, as he states, there are some features of the association of the two minerals that are difficult to account for through this explanation.

The Goldfield occurrence offers little in support of the view that the wurtzite has resulted from an external attack on the sphalerite by acid solutions. If both minerals originated by deposition from solution, present relations would indicate the sphalerite to be younger than at least a part of the wurtzite. If, however, one mineral has undergone enantiotropic change to the other, it is difficult, if not impossible, to determine which was the primary form, as such a change would not necessarily begin at the surface of a crystal grain.

[5] Op. cit., pp. 149–150. 1913.

That sphalerite, under natural condition, may change by molecular rearrangement into wurtzite was suggested by Laspeyres[6] and more definitely stated by Noetling,[7] who concluded as the result of his investigation that sphalerite is primary and wurtzite secondary in origin.[8]

The conclusion that when sphalerite and wurtzite are associated, the wurtzite is generally of secondary origin appears to have considerable support from direct observations; but this relation, if it is true, still lacks satisfactory explanation. If, for example, the wurtzite has been deposited by descending acid solutions, it is not clear why it should be so intimately associated with or replace the less soluble sphalerite. On the other hand if sphalerite, theoretically the more stable mineral at ordinary temperatures, undergoes change to wurtzite, the cause of this change is equally obscure. Although it is well known that sphalerite may be changed to wurtzite by heating to about 1100°C.,[9] this is probably not a common natural mode of formation of the latter mineral. Whether the change of sphalerite into wurtzite can be effected by treatment with acid solutions at moderate temperatures has not been determined so far as I am aware, but this question appears to be easily within the range of experiment.

The rather inconclusive evidence as to the paragenetic relationship of the two zinc sulphides at Goldfield leaves the mode of origin of the wurtzite in doubt. The suggestion is favored that the wurtzite is later than the sphalerite and represents a molecular rearrangement of that mineral. But the explanation originally offered for the deposition of the ores through a mingling of alkaline and acid solutions is quite in harmony with the supposition that the sphalerite and wurtzite crystallized at approximately the same time.

[6] Laspeyres, H., Mineralogische Bemerkungen, Zeits. f. Krist., **9**: 191. 1884.

[7] Noelting, J., Ueber das Verhältniss der sogenannten Schalenblende zur regulären Blende und zum hexagonalen Wurtzit. Inaug. Diss., Kiel, p. 28. 1887.

[8] "Jedenfalls beweisen die Untersuchungen der Blenden von Stollberg, Scharley, Bleischarley, Altenberg, Wiesloch und Miechowitz, dass die Blende primären und der Wurtzit secundären Ursprungs sein muss" (p. 29).

[9] Allen, Crenshaw and Merwin, op. cit., p. 344.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

BACTERIOLOGY.—*The characteristics of bacteria of the colon type found in bovine feces.* L. A. ROGERS, WILLIAM MANSFIELD CLARK, and ALICE C. EVANS. Journal of Infectious Diseases, **15**: 100-123. July, 1914.

Previous work on a collection of the colon type from milk demonstrated that the gas ratio and volume are constant under uniform conditions; that, on the basis of the gas ratio and volume, the cultures may be divided into two distinct groups; and that the correlation of the fermentative ability with the gas ratio makes this distinction sharply defined.

This paper records the results of a similar study on 150 cultures isolated from bovine feces. None of these cultures liquefied gelatin and all but one formed indol from tryptophan. By the use of a simple medium and exact methods of analysis, it was found that in 149 cultures the CO_2: H_2 ratio varied only from 0.98 to 1.20. One culture only gave a ratio identifying it with the high-ratio group, which made up 48 per cent of the milk series.

The 149 low-ratio (0.98–1.20) cultures were readily divided into two groups, one of which fermented dextrose, saccharose, lactose, raffinose, mannite, glycerin and dulcite, but almost invariably failed to ferment starch, inulin and adonite, while the second group fermented adonite and dulcite and failed to ferment saccharose, raffinose, starch and inulin.

These groups agree almost perfectly with two groups which may be formed from the low-ratio cultures isolated from milk. Special methods failed to give evidence, with the exception of the single culture mentioned, of the presence in bovine feces of the high-ratio group, which made up about one-half of the milk collection. L. A. R.

BACTERIOLOGY.—*Bacteria concerned in the production of the characteristic flavor in cheese of the Cheddar type.* ALICE C. EVANS, E. G. HASTINGS, and E. B. HART. Journal of Agricultural Research **2**: 167–192. June, 1914.

The organisms constantly found in Cheddar cheese in such numbers as to indicate they must function in the ripening process may be divided into four groups: First, the *Bacterium lactis acidi;* second, the *Bacterium casei;* third, Streptococcus; fourth, Micrococcus. Each of the four groups may be divided into a number of varieties on the basis of the fermentation powers.

The flora of raw milk cheese consists of all the varieties into which the four groups were divided; but the flora of pasteurized milk cheese, with the exception of the *Bacterium casei* group, is dependent upon the flora of the starter.

No Cheddar flavor is obtained in pasteurized milk cheese when the organisms of the *Bacterium lactis acidi* group alone are used as starters. The quality of the cheese is improved when starters composed of a certain combination of *Bacterium lactis acidi* and Streptococcus are added to pasteurized milk. A. C. E.

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